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Title of Invention

Lawnmower Rotary Cutting Apparatus and Grass Guide

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Cross Reference to Related Application

[0002] This nonprovisional utility patent application was filed within one year of and claims a domestic priority date of November 18, 2003 based on U.S. Provisional Patent Application 10/715,192, filed November 18, 2003.

Statement Regarding Federally Sponsored Research

[0003] No federal funds were used to sponsor any of the research related to the development of the invention described in this patent application.

Names of Parties to a Joint Research Agreement

[0004] The development of the invention described in this patent application is not the product of any joint research and development agreement.

Background of the Invention

[0005] Field of the Invention: Most conventional lawnmowers cut the lawn using one or more large metal blades rotating in a plane of rotation that is substantially parallel to the land surface beneath the grass being mowed. Additionally, most conventional lawnmowers have some type of blade height adjustment. Blade height adjustments are typically achieved by raising or lowering the lawnmower chassis relative to the land surface, and may require a fair amount of time and additional tools. These adjustments can be used to reduce the power required to cut the lawn by raising the blade. However, once a blade height is selected the height and thickness of the lawn and the velocity in which the mower is moved through the lawn determine the blade's cutting area and commensurate amount of power required by the lawnmower. To accommodate the wide variety of grass heights

and densities while providing for adequate speed of forward movement to satisfy the user, most lawnmowers are powered by internal combustion engines of significant horsepower. Moreover, mowers utilizing a plurality of large blades, such as riding mowers or large-swath mowers towed by a tractor, typically require gearing mechanisms to achieve increased speeds, and may become bogged down and stall in high, dense grass at high speeds.

[0006] Electric motors of equal horsepower are also used to power conventional lawnmowers, but finding an efficacious power source to drive such electric motors has proven challenging. For instance, the batteries required to supply enough power for an adequate mowing time are typically prohibitive in size, weight and expense, while the typical home (20-amperes) circuit restricts power supplied by a power cord. Furthermore, a cord also restricts ease of movement of the lawnmower, as well as the distance the mower can travel from the outlet into which the cord is plugged.

[0007] The combination of one or more large blades and a powerful internal combustion engine or electric motor also presents a safety hazard, since the blade is capable of cutting with significant force. A further drawback is the relatively large size and weight of lawnmowers utilizing a powerful internal combustion engine or large electric motor, which reduces the ease of lawnmower operation and storage. With respect to lawnmowers powered by internal combustion engines, a further drawback is that the user typically incurs the cost of purchasing oil and gasoline or other flammable fuel and stores it at his or her home in volumes adequate to fuel the mower for a number of uses, creating a potential fire hazard at the home. Internal combustion engines also produce carbon dioxide emissions which may have a negative impact on air quality and the environment. Finally, when conventional lawnmower blades become periodically dulled and in need of replacement, the blade replacement process may be quite cumbersome to the average user, requiring substantial time and additional tools.

[0008] Description of the Related Art: U.S. Patent No. 3,070,938 ("the '938 patent) discloses a lawnmower comprising a plurality of individual blade units that operate together as a unit in order to

cut a wider swath than mowers existing in the art at the time of the invention embodied therein. The apparatus disclosed in the '938 patent was designed for attachment to a tractor or other powered vehicle and was designed to be raised and lowered in order to follow the topography of the land surface being mowed. While the planes of rotation of the plurality of blades described in the '938 patent are not at all times perfectly parallel to the land being mowed when the mower is in use, they do remain substantially parallel to the land surface, and the cutting area of each blade of the invention embodied in the '938 patent is thus greater than that of the blades used in the present invention. The reduction in cutting area is a significant feature of the present invention inasmuch as the amount of power required is reduced as compared to the plurality of blades used in the invention disclosed in the '938 patent. This enables the use of alternative power sources such as batteries in the present invention to power the cutting blades while an internal combustion engine powering a separate vehicle is required in order to enable the invention of the '938 patent.

[0009] U.S. Patent No. 5,761,892 (the '892 patent) discloses a rotary blade for a rotary lawnmower that provides an equivalent cut to the invention of the '938 patent with a reduction in necessary driving power. The reduction of power described in the invention of the '892 patent is achieved by affixing a plurality of individual cutting elements to a single support arm rotating about a single rotary drive shaft, each cutting element of sufficient length and projecting downward at a suitable angle such that the cutting elements cut the grass as the support arm rotates at a height above the grass. The present invention differs from that embodied in the '892 patent because each of the plurality of blades has its own drive shaft and the drive shafts are situated at an angle tilted longitudinally between ~~1~~5 and 90 degrees from vertical. Moreover, each drive shaft of the present invention may be powered by an individual motor that uses only the power necessary to power the blade affixed thereto to cut the grass in its cutting path, thereby increasing the overall efficiency of the apparatus as a whole by requiring only the energy actually necessary to cut the grass in the path of each discrete member of the plurality of blades.

Brief Summary of Invention

[0010] The present invention embodies a lawnmower consisting essentially of a rotary cutting apparatus and grass guide. In a conventional mower, the blade's drive shaft is arranged such that it remains substantially perpendicular to the blade and horizontal plane of the mower. Therefore, the blade rotates in a substantially horizontal plane. Our invention ~~is novel and unique~~ differs from such conventional mowers because the blade~~'~~s' drive shafts are tilted between ~~1~~5 and 90 degrees in the longitudinal direction from vertical. Therefore, the blades in our invention rotate in a plane tilted longitudinally at least ~~1~~5 degrees from horizontal (Fig. 5). Many present day push and self-propelled lawnmowers have about a 22 inch width which allows the horizontal plane of the mower to remain substantially parallel to ground plane. The horizontal plane of the present invention ~~would~~ also remains substantially parallel to ground plane. While additional blades could easily be added to make our design wider than the typical 22 inch cutting width, a wider design would be limited to a width that allowed the horizontal plane of the mower to remain substantially parallel to ground plane.

[0011] More particularly, the rotary cutting apparatus comprises a plurality of small blades affixed to the end of individual drive shafts, with their planes of rotation substantially perpendicular to their respective drive shafts and to the grass guide throughout their range of adjustment (see Figs. 1, 5 and 6). The grass guide is situated ~~forward with respect to the plurality of blades~~ substantially parallel to the drive shafts, ~~projecting downward~~ positioned at a height suitable for bending ~~the~~ grass of sufficient height in the path of the plurality of blades and restricting the motion of the grass for easier cutting. The rotation of the tilted small blades working in conjunction with the grass guide results in a more efficient cutting design by virtue of a reduction in the cutting area of each blade. This is accomplished by the grass guide bending the incoming uncut grass such that the uncut grass is only cut when the tilted blades are in the lower portion of their planes of rotation, reducing the power required by each blade to cut the grass in contrast to a conventional lawnmower, the power

requirements of which are determined mostly by the velocity at which a mower is moved through the lawn. Additionally, the movement-constraining function of the grass guide makes it easier for the plurality of blades to cut the grass.

[0012] A purpose of the plurality of small blades is a significant savings in required rotational kinetic energy due to the large reduction in mass of the plurality of blades relative to that of a conventional lawnmower blade. Also by virtue of the large reduction in mass of the plurality of blades, as well as a reduction in the mass of the required power source relative to a conventional lawnmower (e.g., a plurality of small electric motors instead of an internal combustion engine), the lawnmower embodied herein is smaller, quieter, lighter and easier to operate and store than a conventional lawnmower. Moreover, the plurality of electric motors utilized in ~~the~~ a preferred embodiment of this invention would produce no carbon dioxide emissions, conferring upon it an environmental advantage over conventional lawnmowers.

[0013] Another purpose of this novel lawnmower is to improve operating safety over that of traditional mowers by using a plurality of small blades operating with significantly less power than a conventional lawnmower. At least one published study indicates that some 80,000 Americans visited emergency rooms in 2004 as a result of lawnmower injuries, and that such injuries have been on the rise.

Brief Description of the Several Views of the Drawings

[0014] FIG. 1 is a side view of a lawnmower utilizing the rotary cutting apparatus and grass guide in accordance with the preferred embodiment of the present invention. In this Figure the axis of the drive shafts is adjusted to 45 degrees from vertical.

[0015] FIG. 2A is a top view of the blade's cutting area in black as a lawnmower is moved forward at a velocity v_1 and rotating at RPM_1 for a single blade of the preferred embodiment of the present invention.

[0016] FIG. 2B is a top view of the blade's cutting area in black as a lawnmower is moved forward at a velocity ν_2 and rotating at RPM_2 for a single blade of the preferred embodiment of the present invention.

[0017] FIG. 3A is a top view of the blade's cutting area in black as a lawnmower is moved forward at a velocity ν_1 and rotating at RPM_1 for the blade of a conventional lawnmower.

[0018] FIG. 3B is a top view of the blade's cutting area in black as a lawnmower is moved forward at a velocity ν_2 and rotating at RPM_2 for the blade of a conventional lawnmower.

[0019] FIG. 4 is a front view of a lawnmower utilizing the rotary cutting apparatus and grass guide in accordance with the preferred embodiment of the present invention.

[0020] FIG. 5 is a side view of a lawnmower utilizing the rotary cutting apparatus and grass guide in accordance with the preferred embodiment of the present invention. In this Figure the axis of the drive shafts is adjusted to 5 degrees from vertical.

[0021] FIG. 6 is a side view of a lawnmower utilizing the rotary cutting apparatus and grass guide in accordance with the preferred embodiment of the present invention. In this Figure the axis of the drive shafts is adjusted to 90 degrees from vertical.

Detailed Description of the Invention

[~~0020~~0022] The present invention is that of a rotary cutting apparatus that comprises a plurality of small cutting blades, each cutting blade rotating about the end of a drive shaft driven by a power means, and a grass guide that constrains the movement of the individual grass blades such that the grass blades are cut by the outermost areas of the radii of the cutting blades (see e.g., FIG. 1). The drive shafts may be collectively powered by a single motor, or, more preferably, each drive shaft may be powered by an individual motor subject to differential power distribution that utilizes only the minimum power necessary to cut the blades of grass within the cutting area of the cutting blade

attached to the drive shaft. An individual motor or a plurality of motors used to power the drive shafts and cutting blades may draw power from any source, including but not limited to an internal combustion engine, a hybrid power source powered by both internal combustion and electricity, an electrical extension cord plugged into an electrical outlet, a fuel cell, a battery or batteries, or a battery or batteries combined with a solar source, or a solar source alone.

[~~0021~~0023] FIG. 1 depicts the side view of an embodiment of the rotary cutting apparatus, and serves to illustrate the benefits and versatility to be derived from the design of the invention. Each cutting blade (1) of the apparatus is mounted to the end of an individual drive shaft (7), the rotation of which is powered by a power means (2), most preferably consisting of a small electric motor mounted to the grass guide (6), powered by one or more low-voltage batteries. FIG. 1 further depicts a side view of the grass guide (6) as a thin rectangle projecting downward substantially parallel to the drive shafts and continuous with a semicircular extension positioned above the assembly of the power means (2), shafts (7) and cutting blades (1). The chassis (5) of the apparatus~~,~~ provid~~ing~~es an adjustable mounting surface for the grass guide (6)~~ and power means~~. The wheels (3) are fixed to the chassis by way of wheel axles. FIG. 1 further illustrates the adjustability of the grass guide at the high point of the apparatus, shown by a curved double-sided arrow beneath the semicircular extension of the grass guide (6). The angular range of ~~1~~5 to 90 degrees from vertical (designated as 0 degrees) is shown to designate the limits of the adjustment, with two curved, double-sided arrows between either ~~1~~5 or 90 degrees from vertical and the current position of the shaft in the drawing (~~about~~ 45 degrees). The full range of angular adjustment is best appreciated by referring to FIGs. 1, 5 and 6 together. In FIG. 5, the angle of the axis of the grass guide and drive shafts is set at 5 degrees from vertical. In FIG. 1, said angle is set at 45 degrees from vertical. In FIG. 6, said angle is set at 90 degrees from vertical. In a preferred embodiment of the invention, the adjustable mounting surface for the grass guide~~ adjustment~~ is positioned at a high point for ease of access by the end user. FIG. 1 further depicts the handle (4).

[~~0022~~0024] The rotary cutting apparatus depicted in FIG. 1 has its drive shafts (7) and grass guide (6) ~~situated at~~ adjusted to an angle ~~adjustably tilted between 15 and 90~~ of 45 degrees in the longitudinal direction from vertical. The cutting blades are arranged substantially perpendicularly to their respective drive shafts. The angular adjustment (5 – 90 degrees from vertical, see FIGs. 1, 5 and 6) capability allows the cutting area of the blades to be controlled. As the angle is increased the cutting area becomes smaller. ~~This angle is relative to the chassis and wheels. Therefore, the~~ The angle of the drive shafts is adjusted without affecting the orientation of the chassis and wheels.

[~~0023~~0025] ~~In FIG. 1 the grass guide is shown as a straight structure fixed to the combined plurality of blades (1), drive shafts (7) and power means (2) and titled longitudinally as a unit with the drive shaft angles between 1 and 90 degrees from the vertical.~~ In FIG. 1, the power means (2) is shown mounted to the grass guide (6), and the drive shaft (7) extends downward in parallel orientation to the grass guide (6), with the cutting blade (1) affixed perpendicularly to the end of the drive shaft (7). As a result, when the angle of the grass guide is adjusted between 5 and 90 degrees from vertical as previously described (FIGs. 1, 5 and 6), the angle of the power means (2), drive shaft (7) and cutting blade (1) is adjusted along with it, and thus the spatial and angular relationships among these parts are maintained throughout the range of adjustment. In FIG. 1 the functional part of the grass guide (6) is shown as a straight, rigid structure ~~situated directly forward of the cutting blade (1)~~ which projects downward ~~at an angle~~ in substantially parallel orientation to the drive shaft (7) and substantially perpendicular orientation to the blade~~'~~s' plane of rotation. FIG. 4 shows the grass guide as a straight structure spanning the width of the plurality of drive shafts (7). The location and angle of the grass guide enables it to perform two unique functions. The first is to limit the cutting area of the blades, thus~~ly~~ reducing the power needed to cut the grass. The second is to bend and constrain the uncut grass ~~in front of the cutting blades such that the uncut grass's movement is restricted and it is presented to the blades in a more perpendicular fashion for more efficient cutting by the blades~~ of sufficient height to contact the grass guide prior to encountering the cutting blades.

~~in front of the cutting blades such that the sufficiently tall~~ Upon contacting the grass guide the uncut grass is bent such that its movement is restricted and it is presented to the blades in a more perpendicular fashion to facilitate cutting. The grass guide (6) in FIG. 1 is shown bending the incoming grass and holding it in a rigid position such that the portion of the blade in the lower portion of the plane of rotation contacts the grass, but other portions of the blade do not. FIG. 2A illustrates the cutting area (8) of a single blade at a forward velocity v_1, rotating at RPM_1 for the preferred embodiment of the present invention. FIG. 2B shows the blade's cutting area (9) as the apparatus is moved forward at a velocity v_2, rotating at RPM_2, for a single blade of the preferred embodiment of the present invention. In contrast to FIG. 2A, FIG. 3A shows the cutting area (10) of the blade of a conventional lawnmower as it is moved forward at velocity v_1, rotating at RPM_1. FIG. 3B further shows the blade's cutting area (11) as the conventional lawnmower is moved forward at velocity v_2, rotating at RPM_2.

[~~0024~~0026] RPM_2 is set to have a smaller value than RPM_1 and is used to indicate times when the RPM of the blade is reduced due to increased loading as the mower encounters thicker and taller grass. Forward velocity v_2 is set to have a larger value than v_1 and is used to show the effect of greater forward velocity. FIGs. 2A and 2B serve to illustrate one of the benefits of the present invention. The grass guide and the angle of the blade from the plane of the cutting surface reduce the blade's cutting area. This means that in areas where the grass becomes too thick and tall, or when the forward velocity becomes too great some portions of the grass will remain uncut. In other words, this design limits the blade's cutting area. Consequently, the maximum amount of power required is limited by this design. This is in contrast to a conventional lawnmower in which the blades cutting area is not limited, as shown in FIGs. 3A and 3B. With a conventional lawnmower, in areas where the grass becomes too thick and tall or when the forward velocity becomes too great the mower will stall. In the present invention, the combination of reducing the blade's cutting area and

constraining the movement of the grass with the grass guide results in a more efficient cutting design than that of a conventional mower. However, when the grass guide is set at very acute angles such as 5 degrees from vertical as depicted in FIG. 5, it is possible that the cutting area of the blades will not always be limited to the lower-most portions of their planes of rotation. This could be compensated for by decreasing the forward velocity at which the mower is traveling across the cutting surface, or increasing the RPMs of the motors.

[~~0025~~0027] FIG. 4 illustrates a plurality of cutting blades (1), a power means consisting of a plurality of small motors (2), wheels (3), a handle (4), a chassis (5), a grass guide (6), and a plurality of drive shafts (7) driving the cutting blades (1). FIG. 5 is a side view of the lawnmower with the drive shaft tilted at an angle of 5 degrees from vertical. FIG. 6 is a side view of the lawnmower with the drive shaft tilted at an angle of 90 degrees from vertical. In FIGs. 1, 5 and 6 two horizontal lines labeled A and B are shown. In FIG. 5 an additional horizontal line labeled C is shown. In each of FIGs. 1, 5 and 6, horizontal line A is drawn at the bottom-most portion of the grass guide, and horizontal line B is drawn at the lowest end of the blade when set at the position depicted in the drawing. Line A always remains at a greater height from the ground surface than line B throughout the full range of adjustment of the grass guide (6). This is true for all blades even if the lower ends of each blade are not in perfect horizontal alignment with each other. In FIG. 5, horizontal line C is drawn to indicate the approximate height the uncut grass must be in order to be bent and constrained by the grass guide when the grass guide is set at the depicted angle prior to being cut as the mower is moved forward. FIGs. 1 and 6 show that all uncut grass that is taller than line A will be bent and constrained by the grass guide prior to being cut as the mower is moved forward when the grass guide adjustment is set at the depicted angles.

[0028] This invention uses small blades whose outer radii overlap the cutting region of the grass bent and constrained by the grass guide. The plurality of blades provides for an adequate cutting

width comparable to that of a conventional manual lawnmower. The rotational kinetic energy of each blade is its ability to do work because of its motion and is usually expressed as Equation 1:

$$K = \frac{1}{2} I\omega^2,$$

where I is the moment of inertia of the blade and ω is its angular velocity. For a rectangular blade with its axis through the center, I, the moment of inertia is expressed as Equation 2:

$$I = \frac{m}{12}\left(l^2 + w^2 + h^2\right),$$

where l is the length, w is the width, h is the height or thickness and m is the mass of the blade. The mass of the blade may be obtained by multiplying the density of the blade by the blade volume. The total rotational kinetic energy required by a plurality of small blades is the sum of the rotational kinetic energies required for each small blade. Since the cutting speed of a rotary blade is a function of both the angular velocity and the distance from the axis of rotation, the angular velocity of the plurality of small blades must be increased to be similar to the cutting speed of a single large blade. This increase in angular velocity has the additional advantage of providing greater cutting frequency. By using small, high RPM electric motors, one can easily increase the angular velocity of a plurality of small blades. For the present invention, the angular velocity will be increased, while the largest blade dimension, length, will be decreased relative to a conventional lawnmower. Even though the product of the two squared terms l and ω in Equation 1 will be approximately equal for a conventional mower and the present invention, a large savings in rotational kinetic energy of the present invention will come from a significant decrease of mass, m, in Equation 2.

[~~0026~~0029] Increasing the angular velocity of a plurality of small blades using a single electric motor or a conventional internal combustion engine, however, may require a gearing mechanism. Using a plurality of small electric motors has the additional advantage that each motor can be connected directly to the blade's driveshaft and no separate mechanical drive mechanism would be required as with a single motor system. Use of an electric motor or motors results in additional

power savings since each motor would independently draw additional current only as its load increased. The reduced weight and size resulting from the use of a plurality of small motors is a further advantage of this design. One of the greatest differences between the present invention and a conventional mower is the mass of the blades. By significantly decreasing the mass *m* in Equation 2 through use of a plurality of small blades, the rotational kinetic energy of the disclosed invention is significantly reduced from that of a conventional mower. An experimental apparatus has been built which demonstrates this significant reduction in required rotational kinetic energy.

[~~0027~~0030] The blades, drive shafts, and power means of the present invention are affixed to a chassis, most preferably constructed from durable but lightweight metal or plastic, with a means affixed to said chassis that allows said chassis to move about the ground laterally and longitudinally to facilitate the ability of the blades to cut the grass, most likely wheels ~~(FIGs. 1 and 4).~~ (FIGs. 1, 4, 5 and 6). As with a conventional lawnmower a blade height adjustment will be present. A handle may be affixed to the lawnmower in order that a person may be able to more easily push or pull the lawnmower laterally or longitudinally about a land surface in order to cut the grass growing thereon ~~(FIGs. 1 and 4).~~(FIGs. 1, 4, 5 and 6). Alternatively, the apparatus may be robotically propelled about the land surface on which the grass to be cut grows in order to cut the grass, eliminating the need for a handle for manual propulsion.

[~~0028~~0031] The use of a smaller, lighter motor or motors relative to those most typical of conventional lawnmowers results in a smaller, quieter, lighter lawnmower, which is easier to operate and store. Another advantage of this design is that the use of a plurality of small blades, operating with significantly less power than a conventional lawnmower, improves operating safety. These improvements in safety, lightness and smallness would benefit both user-operated lawnmowers and self-guiding, robotically propelled lawnmowers. Since the total mass and volume of the plurality of small blades will be significantly less than one large blade, new blade designs and different and possibly less expensive construction materials can be used. New small blade designs can further

reduce the power requirements. For instance, the blade can be designed aerodynamically to have very little air resistance, thereby further reducing the required rotational kinetic energy. Like a conventional mower the blades can be made from metal, typically hardened steel. However, like an electric or gas trimmer the blades could be made from plastic or metal or some combination of plastic and metal. They could be as simple as a nylon plastic line or more complex as a nylon plastic mold with serrated stainless steel inserts. An environmental advantage of using the preferred power source of a rechargeable battery or combination of solar panels and rechargeable battery is that the mower would not produce carbon dioxide emissions and would not require any gas or oil. Since both the blades and motors are small and inexpensive they could be designed for easy replacement in the event of failure or damage.